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ABSTRACT

Part II of the study describes a model for associating one portion of total library costs with use; the model's output is a set of charges that can be used to recover (justify) these usage-based costs. Algebraic formulations constructed and combined to form the model are a set of service charges that may vary by user type and recover out-of-pocket costs and some variable portion of support costs. Provision is also made for a per capita charge on the user population to recover any variable support costs that are not recovered through the service charges. These algorithms were first used to develop a static model of cost recovery dealing with only a single time period to meet one period budget, and then adapted to illustrate how it can be used to cover multiple time periods. The model was run using an estimated line item budget, and generated overall usage data by institution, unity charges output, consequent usage-based assessments to each institution by service, and the total assessments. The non-variable or fixed support costs that are to be recovered through fees charged to institutions housing groups of members are modeled and analyzed in Part III. (Author/JPF)

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Research Report CCS 302

# COSTS AND THEIR ASSESSMENT TO USERS OF A MEDICAL LIBRARY, PART II: RECOVERING COSTS FROM SERVICE USAGE

by

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July 1977

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IR 006 303

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## PREFACE

This report covers the results of a study that began October 1, 1974 and ended March 31, 1977; originally scheduled for completion in two years, various problems extended the study period to 30 months. Viewed in terms of the goals established in the proposal, the study has succeeded. Indeed, to the extent that an operational cost assessment model is now being used as an adjunct to administrative decision making at the principal study site, the study can be judged to have had significant impact that will probably spread to other similar institutions.

The study team was co-directed by Abraham Charnes, Director of the Center for Cybernetic Studies (CCS) and University of Texas System Professor and Jesse H. Jones Professor of Biomathematics and Management Science, and Sam W. Hitt, former Executive Director of the Houston Academy of Medicine-Texas Medical Center (HAM-TMC) Library. Other members of the study team were:

1) Milton E. F. Schoeman (Senior Investigator), Associate Professor of Management at the Graduate School of Business, University of Texas at Austin.

2) Richard A. Lyders (Administrative Associate), current Executive Director of the HAM-TMC Library.

3) Diane Cole Eckels (Research Associate), Associate Director of the HAM-TMC Library.

4) Keith Russell (Project Coordinator), former Research Librarian at the HAM-TMC Library.

5) Edward S. Bres, III (Research Assistant), Ph.D. candidate at the Graduate School of Business, University of Texas at Austin.

6) John J. Rousseau (Research Assistant), Ph.D. candidate at the Graduate School of Business, University of Texas at Austin.

7) Donna Robinson (Clerical Assistant), former staff member at the HAM-TMC Library.

As can be seen from the composition of this team, the study was structured as a joint venture, using a team approach in pursuing the goals. The HAM-TMC Library was the "site" for information, data gathering, testing and implementing the results, while the University of Texas Center for Cybernetic Studies was the site for analytical and computational methods of development. Much of the detailed description of this arrangement and other information regarding the format and pursuit of this study can be found either in the formal proposal or the previously distributed "Progress Report: October 1, 1974-September 30, 1975."

This final report is divided into four parts, each describing a separate study issue:

Part I- "An Overview of Services, Users and Budgeting in a Medical Library" discusses the general administrative concerns prompting this study initially. Briefly stated these concerns can be summarized in the question "how can the cost of a library be equitably allocated to its supporters in justifying its budget?"

Part II- "Recovering Costs from Service Usage" describes a model for associating one portion of total library costs with usage; the model's output are a set of

charges that can be used to recover (justify) these usage-based costs.

Part III- "Allocating Fixed Joint Costs" describes a model for completing the cost assessment (justification) process by accounting for the fixed joint costs; a "fair" and equitable mechanism is developed in the context of a game-theoretic approach.

Part IV- "Differences in the Use of a Health Science Library by Various Users" is a summary analysis of sample and survey data collected to facilitate the structuring of the cost assessment models. The results correlate well with previously discussed observations and extend some of them into new directions.

Although some references are made to other parts in the report, each part is written as a reasonably self-contained unit. Thus, readers may selectively choose to focus on only those topics of immediate interest and not need to read the entire report.

It should be explicitly noted that the data and relations ascribed to the HAM-TMC Library are real. The output assessments provided in one part have actually been used in the most recent budgeting cycle. Further refinements in the model are necessary, but the current version is already providing the library administration with a unique and practical tool for developing and analyzing its budget. It is anticipated that similar successful application can be made in other libraries once information in this report is

circulated.

Finally, the assistance of many staff members and professionals, both at the University of Texas and the HAM-TMC Library, is gratefully, albeit anonymously, acknowledgeed. Without the support and wholehearted cooperation of the National Library of Medicine and its project monitoring staff this study could not have been undertaken and carried through. The study team accepts full responsibility for the contents of this report and any criticisms should be directed to them.

CCS, Austin; HAM-TMC Library, Houston

July, 1977

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## PART II

## RECOVERING COSTS FROM SERVICE USAGE

### II-1. Introduction

The conceptual thrust of this study has been to identify how costs arise in the formation and operation of a service institution like a library that provides a variety of related and interrelated services to a heterogeneous mix of users.[1] It is possible, then, to construct a means for recovering these costs (i.e., supporting the library's budget) through assessments to the institutions housing the users. Even if direct institutional assessment or subscription is not necessary because the library is supported through other means (e.g., as part of a general operating budget for a university), such a cost allocation process is useful to monitor performance and establish patterns of growth and expanding needs for resources.

A reasonable division of the costs distinguishes those attributable to each specific direct service provided (called out-of-pocket costs) and those essential to general library operations as an integrated facility (called support costs). Care must be exercised in the assignment of our identification of costs in our model to usual accounting categories of direct and indirect expenses since these, as well as

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[1] The reference here and elsewhere to "users" usually indicates the actual persons demanding and receiving the services. Occasionally, groups of users or institutions to which they are affiliated will be referred to as users; such instances will be specifically noted as exceptions in the application of this term.

variable and fixed costs, involve more of a joint cost nature than usual in the special context of a library.

Out-of-pocket costs arise from those direct activities in delivering services to the user. For example, a portion of the cost of personnel who shelve books may be directly attributable to the service of using materials in the building. It is important to note that we characterize the library costs falling into this class as resulting from services directly provided to the user. Thus, out-of-pocket costs are variable in nature, responding to the usage experience of each service.

The support costs, which may be relatively substantial in some libraries, are characteristically more complex to analyze than out-of-pocket costs. A large portion of these costs are related to physical inputs, such as books and journals purchased or plant (space) and equipment leased. Also to be considered are those personnel and their activities that contribute to library operations overall, but at levels not determined by the quantity of direct library usage. For example, the technical services personnel and material costs are dependent upon the number and types of publications purchased and policies of processing and are, therefore, related to the programs of the institutions using the library rather than actual usage of the collection. One aspect of support costs, then, arises from the necessity to establish and maintain a basic facility with the requisite capacity to provide a predetermined set of services for its users. In a sense, these costs are relatively fixed with respect to usage once having defined the types of services to be offered.

Difficulties in dealing with these support costs enter when observing that qualitative considerations of service may require changes in supportive facilities and activities as usage varies. For example, the number of duplicates of various materials may increase if usage grows large enough as a means of easing accessibility; observe that the initial material acquisition may be considered fixed as a portion of the library's basic informational configuration, while the duplication is a variable extension of this basic capacity to improve a service in response to its usage. Such quasi-variable aspects of support costs suggest a recovery method that depends on service usage shared among services since in most instances they benefit jointly.

As a result of this discussion we can see that some portion of support costs, which are almost always traditionally considered fixed, are related to direct service usage. Along with the out-of-pocket costs we can structure a cost allocation and assessment model that is based on service usage accounting for part of the library's total operating budget. The relatively fixed elements of the support costs are modeled and analyzed in another part of this report.

The remainder of this part of the report will describe the usage-based model, both algebraically and in its library context. An illustration using the data compiled at the HAM-TMC Library will show what results can be expected and how they may be interpreted.

## II-2. Preliminary Considerations in Model Construction

As has already been stated out-of-pocket costs for services should definitely be recovered through charges for these services, while a variable portion of support costs exists that should be recovered in

some fashion through the charges for all services. Several factors help establish a relationship, indeed a partial hierarchy, in the magnitude of the costs to be recovered through the charges for each service: 1) differences in magnitude that reflect varying types and amount of resource requirements (i.e., professional and clerical personnel, equipment, etc.) for the services themselves, 2) differences indicating administrative charging policies that subsidize some services through nominal excess recovery in others (e.g., charging somewhat less for manual bibliographic searches by adding a few cents to the circulation charge), 3) differences based on historical precedents and consistent administrative practice (e.g., a fully self-sustaining service, such as user photocopying, may be specifically excluded from the cost recovery model since it places virtually no resource burden on the library, its availability enhances the library's service image, and it is not administratively desirable to have it subsidize other services).

Further, as seems outwardly reasonable, and demonstrable within limits (see another part of this report) different users use the library in different ways and should, therefore, be charged in relation to both the quantity and quality of their use of each service. We recognize that a subset of the services offered by a library are used by different user types in varying intensities. This is not only because of varying information needs, but also because of policies of restriction of some services to specific types of users. For example, in some academic libraries telephone reference may be restricted to faculty members.

In addition, the same service (nominally) given to different individuals may differ in terms of costliness. For example, interlibrary

borrows for a medical professional may require more time than those for a medical student. Similarly the most time consuming reference questions may be asked by a particular user group or conversely may seldom be asked by a particular group. These differences suggest that charges for a specific service should not be the same for all users.

Finally, from a broader economic perspective there may be factors that influence the recovery strategy employed with respect to out-of-pocket costs, some services may show economies of scale. For example, in reshelving it should probably not take 100 times as much time to reshelve 100 books as it would 1 book because of batching books to be shelved. That is, the per unit time required would decrease with increased activity. Thus, charges based on average costs for such services would be inappropriate. With respect to variable support costs, some expenses, like maintenance and utilities, are more equitably carried by the total user population on a per capita basis rather than through the usage based service charges. Such a recovery method recognizes the equal distribution of expenses that actually relate to how many people may be in the library over the year regardless of what they are doing (i.e., the services they receive).

In sum, any cost recovery model for the out-of-pocket costs and variable support costs must account for a wide variety of considerations - technical, behavioral, economical, and managerial.

## II-3. The Single Period (Static) Model

To facilitate initial discussion let us develop a static model of cost recovery that deals with only a single time period; later this model can be extended to multiple periods. Cost recovery in this context

implies attempting to meet a library's single period budget as closely as possible through three mechanisms: 1) a set of service charges that possibly vary by user type and recover out-of-pocket costs and some variable portion of support costs, 2) a per capita charge on the user population to recover any variable support costs that are not recovered through the service charges, like utilities and maintenance, 3) the non-variable or fixed support costs that are recovered through fees charged institutions housing groups of users. The rationale for these mechanisms has already been discussed. Let us now structure the algebraic formulations of these mechanisms one at a time and then combine them into a model.

Suppose $d_{ij}$ represents the demand, or usage, of service i by user type j. Except for the per capita recovery process for one part of the variable support costs, this demand is the sole basis for recovering the entire variable portion of the library's operating budget. The relationship between this demand and the costs that accrue from any particular service may take on many different forms. A general algebraic expression representing this relationship may be written as:

$$a_{ij} d_{ij}^{\alpha_i}$$

where $a_{ij}$ can be considered, for now, merely a scaling factor and $\alpha_i$ is a value that can "bend" the shape away from a straight line (linear) one. It should be noted that the only limitation inherent in the algebraic statement given is a failure to account for any relationship that oscillates, a situation considered most unlikely. In fact, since we anticipate certain economies of scale for some services, we can expect the relevant values of $\alpha_i$ to fall in the range $0 < \alpha_i \leq 1$. To observe how choices for $\alpha_i$

change the shape see Figure II-1.

From Figure II-1 it is clear that the smaller one chooses $\alpha_i$, the more economies of scale are assumed present in the delivery of service i. For practical purposes values for $\alpha_i$ were estimated by informed individuals in the library rather than through elaborate statistical analysis.

The relationship between usage and cost leads directly to an expression for unit charge:

$$a_{ij} \frac{d_{ij}}{d_{ij}}^{\alpha_i}$$

Thus, each user type j will pay to recover the costs allocated to service i proportionate to usage. It now remains to demonstrate the means for determining the allocational factor $a_{ij}$ that effectively apportions costs between services and user types.

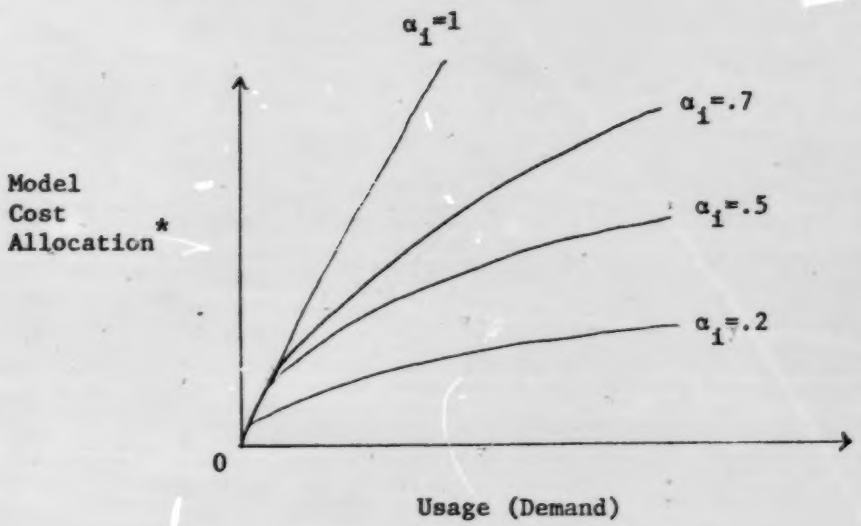
Let us begin with the out-of-pocket costs attributable to service i by user j, represented as $O_{ij}$. Any reasonable cost recovery model will attempt to select values of the $a_{ij}$, given values for the other elements, so that one approaches the multiple goals of out-of-pocket costs as closely as possible. Mathematically, we can state

$$\min \sum_i \left| \sum_j a_{ij} d_{ij}^{\alpha_i} - O_i \right|$$

where the absolute value merely permits some services to be under while others are over their respective out-of-pocket costs but accounts for these discrepancies equally. Additionally, we require that the $a_{ij} \geq 0$ since other values are impractical and unrealistic.

Figure II-1

Economies of Scale in Service Cost




*This axis corresponds to values of $a_{ij}d_{ij}^{\alpha_i}$

We can rewrite our mathematical expression in a linear programming model explicitly containing the deviations of allocated recovery, from cost.

Version 1

$$\min \sum_i g_i^+ + \sum_i g_i^-$$

subject to:

$$\sum_j a_{ij} d_{ij}^{\alpha_i} - g_i^+ + g_i^- = O_i, \text{ all services } i$$

$$a_{ij}, g_i^+, g_i^- \geq 0 \text{ , all services } i \text{ and user types } j$$

where $g_i^+$ represents the excess of allocated recovery over out-of-pocket cost (i.e., over collection)

$g_i^-$ represents the shortfall of allocated recovery below out-of-pocket costs (i.e., undercollection)

Clearly, for each service i we will either undercollect, or overcollect, or equal its out-of-pocket costs and hence, at most only one of its respective $g_i$ terms will be non-zero; in other words, for those services that overcollect, $g_i^+$ will be positive and $g_i^-$ will be zero, while the opposite will hold for services that undercollect, and both $g_i$ terms are zero for exact recovery. Given any standard linear programming solution process and values for the $d_{ij}$, $\alpha_i$ and $O_i$, we would then derive appropriate values for $a_{ij}$ (and also the deviations $g_i^+$ and $g_i^-$).

Three immediate observations can be made from this model formulation:

1) since the objective merely attempts to recover overall out-of-pocket costs as closely as possible and all services are treated the same with regard to deviations, nothing prevents an allocation

in which one service subsidizes the costs, or some part of them, for one or more of the others

2) while the $a_{ij}$ derived from the model have a direct impact on the relative charge structure between services, nothing in the model reflects any predisposed ordering or other relationships in this structure

3) the model does not account for the recovery of the variable support costs that are to be included as part of the service charges

Adjusting the model to accommodate the implied deficiencies in these observations is done in various different ways.

At the discretion of the decision maker deferential weights or penalties can be imposed on the deviations representing varying priority associated with overcollection and/or undercollection for each service. Moreover, with respect to overcollection specifically, some unpenalized slack can even be accommodated by dividing the overcollection deviation variable into two parts, one weighted in the objective and the other not even present. Such a modification encourages overcollection for some services up to a prespecified limit. Incorporating these changes in the preceding model yields:

Version 2

$$\min \quad \sum_i w_i^+ g_i^+ + \sum_i w_i^- g_i^-$$

subject to:

$$\sum_j a_{ij} d_{ij}^{\alpha_i} - g_i^+ - s_i + g_i^- = O_i, \text{ all services}$$

$$s_i \leq B_i, \text{ all services}$$

$$a_{ij},\ g_i^+,\ s_i,\ g_i^- \geq 0,\ \text{all services and user types}$$

where $s_i$ represents the unpenalized overcollection potential for service i (note that all services need not have an $s_i$),

$B_i$ represents the prespecified limit for overcollecting that is unpenalized (some services $B_i = 0$),

$w_i^+$, $w_i^-$ represent the weights or penalties assigned over-collection/undercollection for service i, and

all other elements are defined as before.

We can further modify the model to reflect various structural relationships between the service charges by introducing more constraints. These relationships may arise through a variety of administrative policies some established by historical precedent.

a) There may be prescribed lower bounds on some service charges; that is, for service i

$$a_{ij} \frac{d_{ij}}{d_{ij}}^{\alpha_i} \geq l_i\ ,\ \text{all user types}$$

where $l_i$ is the lower bound.

b) There may be prescribed upper bounds on some service charges; that is, for service i

$$a_{ij} \frac{d_{ij}}{d_{ij}}^{\alpha_i} \leq u_i\ ,\ \text{all user types}$$

where $u_i$ is the upper bound.

c) Some services may be charged more than others; that is, for services i and p

$$a_{ij}\ \frac{d_{ij}}{d_{ij}}^{\alpha_i} \begin{pmatrix} \geq \\ = \\ \leq \end{pmatrix} k_{ip}\ a_{pj}\ \frac{d_{pj}}{d_{pj}}^{\alpha_p}\ ,\ \text{all user types}$$

where $k_{ip}$ represents a prespecified magnitude of difference between these charges and only one of the three relations hold.

d) Some users may be charged more for a given service to reflect differences in their quality of use; that is, for user types j and q

$$a_{ij}\ \frac{d_{ij}}{d_{ij}}^{\alpha_i} \begin{pmatrix} \geq \\ = \\ \leq \end{pmatrix} h_{jq}\ a_{iq}\ \frac{d_{iq}}{d_{iq}}^{\alpha_i}\ ,\ \text{some service i}$$

where $h_{jq}$ represents a prespecified magnitude of difference between these charges and only one of the three relations hold.

It should be emphasized that these constraints arise through non-economic considerations. However, the more stringent these conditions become (e.g., the tighter the bounds on service charges), the less freedom the model has to allocate costs across services and hence, there are trade-offs. They are very difficult to quantify in advance.

To this point, we have of course omitted consideration of variable support costs. As discussed earlier, one portion of this cost (i.e., the utilities and maintenance expenses) are more appropriately associated with the user population and not the services they use. Hence, charges for services will not be adjusted to account for these costs. Rather, some other mechanism, a per capita charge, will recover them. Let us denote this total amount as U. Then, the remaining variable support costs, that are to be recovered through the service charges, can be expressed as a fraction of the whole library budget less U and the total

out-of-pocket costs already considered. In other words, if T represents the whole library budget, then $T-U-\sum_i O_i$ represents the total support costs. As argued previously, some fraction of this total, say f $(0 < f < 1)$, should be recovered through the service charges since it represents qualitative expenditures varying with services and their usages.

Recall, however, that these costs are to be jointly borne by all services by their nature. The mathematical mechanism for introducing this consideration into our model is to allow the total overcollections from all services, that is the excess of allocated recovery over out-of-pocket costs, attempt to meet this cost requirement. Algebraically, we state

$$\sum_i g_i^+ + \sum_i s_i - \varepsilon = f\ (T-U-\sum_i O_i)$$

where $\varepsilon$ represents the measure of how close we get (always from above) to recovering these variable support costs. In a sense, $\varepsilon$ is like a $g_i$ term and must appear in our objective function with a weight appropriate to its relative importance. Notice that we are forcing the recovery of the variable support costs by the form of this constraint. Never will we recover less than this amount.

We can now write a final version of the model as follows:

Version 3

$$\min \sum_i w_i^+ g_i^+ + \sum_i w_i^- g_i^- + w_\varepsilon \varepsilon$$

$$\text{subject to: } \sum_j a_{ij} d_{ij}^{\alpha_i} - g_i^+ - s_i + g_i^- = O_i \text{ , all services } i$$

$$s_i \leq B_i \text{ , all services } i$$

$$\sum_i g_i^+ + \sum_i s_i - \varepsilon = f\,(T-U-\sum_i O_i)$$

$$u_i \geq a_{ij} \frac{d_{ij}}{d_{ij}}^{\alpha_i} \geq l_i \text{ , some services, all user types}$$

$$a_{ij} \frac{d_{ij}}{d_{ij}}^{\alpha_i} \left( \begin{matrix} \geq \\ = \\ \leq \end{matrix} \right) k_{ip}\, a_{pj} \frac{d_{pj}}{d_{pj}}^{\alpha_p} \text{ , some services, all user types}$$

$$a_{ij} \frac{d_{ij}}{d_{ij}}^{\alpha_i} \left( \begin{matrix} \geq \\ = \\ \leq \end{matrix} \right) h_{jq}\, a_{iq} \frac{d_{iq}}{d_{iq}}^{\alpha_i} \text{ , some services, all user types}$$

$$a_{ij},\ g_i^+,\ s_i,\ g_i^-,\ \varepsilon \geq 0$$

The various parameter values in this model will reflect the operating environment of the library and its administrative policies and procedures. It should be noted that the remaining budget not specified in the model above (i.e., $(1-f)(T-U-\sum_i O_i)$) is recovered through an institutional assessment process described in the next part to this report. The linkage of this model to that process is through the value of $\varepsilon$ which can be applied to this remaining cost recovery item.

II-4. The Multiperiod (Dynamic) Model

In practice it would seem desirable to extend the preceding model to cover several time periods. Prospective planning might be useful for several years hence, as an example, if significant capital expenditures were anticipated and their gradual inclusion in several years' budgets were desired. The effect of an expanding market (i.e., user

population) or service capabilities would also prompt a broader analysis of the cost recovery process.

Adaptation of the preceding model to a dynamic, multiperiod context can be accomplished straightforwardly. Initially, all preceding variables and parameters are now subscripted (or superscripted), for time period except the $a_{ij}$ which remain the constant allocational factors throughout. This process implies that values for all parameters will have to be estimated, or otherwise determined, for each time period in the planning horizon; of course, some values may remain unchanged as, for example, the fraction f which seems to be more a matter of policy and time invariant economic logic. Also, the number of constraints will increase to account for individual, period-by-period recovery of the various costs.

The most substantive change is the addition of a series of constraints that effectively couple recovery overall in one time period with that in the next. The form of these constraints relate explicitly to the only portion of the total budget not previously included in our model; that is,

$$\sum_k b_k^t + \epsilon_t - \emptyset_t = (1-f)\left[T^t - U^t - \sum_i O_{it}\right]$$

where $b_k^t$ represents the non-variable (fixed) support cost contribution, called a base fee, assessed to institution k in time period t,

$\emptyset_t$ represents the excess recovery over total library budget in period t and presumably available to apply in period t + 1, and

all other elements are defined as before.

It can be observed that the base fees are charged to the institutions housing the users and have consistently been discussed before as being relatively determined by a process described in the next part to this report. At this stage, however, it is apparent that they must be incorporated into this model since there may be beneficial trade-offs in overcollecting on total budget one period and using this excess subsequently. For example, such a situation may be desirable in order to smooth or level the service charges over time despite fluctuations in budget. The actual trade-off is modeled by placing all the $\phi_t$ terms in the objective function with weights reflecting the priority of this deviation from exact recovery versus the other previously described deviations. Naturally, all the $b_k^t$ and $\phi_t$ are non-negative.

The general dynamic model, then, appears as Version 3 given in the last section modified by indexing variables, parameters and constraints to account for time period, adding some constraints of the form just previously discussed and adding some weighted overcollection variables to the objective function.

II-5. Application to the HAM-TMC Library

The model described above was developed in the context of the HAM-TMC Library whose description appears in an earlier part to this report. Twenty-two institutions were involved with four different user types and eight services accounted for (see Table II-1). As can be seen from the table, this listing represents a selective collection of all possible users and services; however, it was agreed that it would represent a

Table II-1

User and Service Categories

Users:

1. Medical Professionals --M.D.'s, PhD.'s and associated personnel engaged in clinical practice, teaching, and research. Includes faculty, fellows, post doctorates, HAM members, and support staff, as research associates and assistants, secretaries, etc.

2. Nursing Professionals--Nursing and allied health (including occupational therapy and physical therapy) faculty and practitioners, including associated personnel.

3. Medical Students--Includes medical students, interns, residents, GSBS graduate students, UTSPH students, speech and hearing students, and all graduate students (including nursing, occupational therapy, physical therapy graduate students, etc.)

4. Nursing Students--includes undergraduate nursing students, undergraduate allied health students, and high school students.

(Note: Personnel not from member institutions were considered "visitors" whose usage is supported indirectly by the members.)

Services:

1. Self service - use of material in building, study space
2. Circulation
3. Interlibrary loans - within TMC
4. Reference questions under ten minutes - includes telephone holds, paging M.D.'s, holds and rushes, and so on
5. Reference questions over ten minutes
6. Interlibrary borrowing
7. Manual bibliography searches
8. Computerized searches - MEDLINE, SDILINE, SDC services and so on.

useful basis for analysis, and could be expanded later as needed.

Additional survey data and analysis (discussed in some detail later in this report) and extensive communication with library staff and administration yielded Table II-2. It should be noted that the second column in this table shows that for some services various of the user types behaved identically in terms of usage. Hence, types were combined and treated the same where appropriate.

Further deliberations led to the following added specifications:

(i) Services 1 and 2 were not permitted to undercollect (they were the most heavily used services and most easily used as means of subsidizing other services); mathematically, this result made $\bar{g}_{1t} = \bar{g}_{2t} = 0$ for all t

(ii) Services 3 through 8 were permitted to undercollect without penalty; mathematically, this result made $\bar{w}_{3t} = \bar{w}_{4t} = \ldots = \bar{w}_{8t} = 0$ for all t

(iii) It became convenient to define a mean unit charge for services with more than one user type as indicated in Table II-2.

$$a_i = \left[ \sum_{j=1}^{r_i} a_{ij} \frac{(d_{ij})^{\alpha_i}}{d_{ij}^{t}} \right] \div r_i \quad , \; i = 4,5,6,7,8$$

Then, lower bounds were specified on actual unit charges in the case of services 1, 2, 3 and mean unit charges in the case of services 4, ..., 8:

$l_1=0$, $l_2=1.0$, $l_3=2.0$, $l_4=2.5$, $l_5=5.0$, $l_6=7.0$

Table II-2

User, Service and Cost Relations

| Service (i) | Number of Different User Types ($r_i$) | $\alpha_i$ |
|---|---|---|
| (1) Self-service | 1 | .67 |
| (2) Circulation | 1 | .75 |
| (3) Interlibrary loans | 1 | .50 |
| (4) Reference questions under 10 min. | 4 | 1.00 |
| (5) Reference questions over 10 min. | 4 | 1.00 |
| (6) Interlibrary borrowing | 3 | .875 |
| (7) Manual Bibliography Searches | 3 | 1.00 |
| (8) Computerized Searches | 4 | .875 |

$l_7$=10.0, $l_8$=11.0 for all time periods.

Thus, for example, the mean unit charge for a computerized search (service 8), had to at least be equal to $11.00.

(iv) No upper bounds on any service charges (actual or mean); that is, all $u_i = 0$ for all services and all time periods

(v) A variety of relationships were developed between unit service charges (actual or mean). For example, the self service (service 1), unit charge was made the least expensive of all by including seven constraints of the type:

$$a_1 \frac{(d_1^t)^{\alpha_1}}{d_1^t} \leq \begin{cases} a_i \frac{(d_i^t)^{\alpha_i}}{d_i^t}, & i = 2,3 \text{ (actual)} \\ a_i, & i = 4,\ldots,8 \text{ (mean)} \end{cases}$$

Note the value of $k_{1i}$ is 1 in the above relations meaning no explicit differential is required; only that service 1 is least expensive. Other constraints related the other services to each other (see Table II-3).

(vi) Relations on the charges within a specific service for each user type for the last five services were identified; recall that these types are listed in Table II-1. As an example of such relationships, the following were formulated for the case of interlibrary borrowing (service 6):

Table II-3

Relationships between unit charges for all services

| Algebraic Form | Interpretation |
|---|---|
| $a_1 \frac{(d_1^t)^{\alpha_1}}{d_1^t} \leq \begin{cases} a_i \frac{(d_i^t)^{\alpha_i}}{d_i^t}, & i=2,3 \\ a_i, & i=4,\ldots,8 \end{cases}$ | Self service (1) has smallest unit charge |
| $2a_4 \leq a_5$ | Mean unit charge for reference questions under ten minutes (4) will be less than half that for those over ten minutes (5) |
| $2a_5 \leq a_8$ | Mean unit charge for reference questions over ten minutes (5) will be less than half that for computerized searches (8). |
| $a_7 \geq a_8$ | Manual bibliography searches (7) will be charged more than computerized searches (8) |
| $a_2 \frac{(d_2^t)^{\alpha_2}}{d_2^t} \leq a_7$ | Circulation (2) will be charged less than manual bibliography searches (7) |
| $a_3 \frac{(d_3^t)^{\alpha_3}}{d_3^t} \leq a_7$ | Interlibrary loans (3) will be charged less than manual bibliography searches (7) |
| $2a_3 \frac{(d_3^t)^{\alpha_3}}{d_3^t} \leq a_6$ | Interlibrary loans (3) will be charged less than half of the mean amount for interlibrary borrowing (6) |

$$a_{62}\frac{(d_{62}^t)^{\alpha_6}}{d_{62}^t} \leq a_{61}\frac{(d_{61}^t)^{\alpha_6}}{d_{61}^t} \leq 1.6a_{62}\frac{(d_{62})^{\alpha_6}}{d_{62}^t}$$

$$a_{62}\frac{(d_{62}^t)^{\alpha_6}}{d_{62}^t} \leq a_{63}\frac{(d_{63}^t)^{\alpha_6}}{d_{63}^t}$$

These relationships imply that nursing professionals will be assessed a unit charge for this service lower than or equal to that assessed either medical professionals or medical students. However, the unit charge carried by the medical professionals cannot be more than 60% higher than that for the nursing professionals. There is no direct relationship between the unit charges for medical professionals and me medical students. It should be noted that none of the inequalities forces an explicit set of values to occur; rather they maintain a limited ordering among the values including the possibility that all values for the unit charges will be equal to each other. Each of the other four services with different user types had similar constraints; the explicit formulations are not given here in the interest of brevity, however, their justification is discussed in somewhat greater detail later in this report when analyzing different users and their characteristics.

(vii) All services were permitted to overcollect without penalty if the lower bounds on their unit charges caused them to recover in excess of their out-of-pocket costs; beyond this point (i.e., if unit charges were made higher than their lower bounds and out-of-pocket costs were already being exceeded) overcollection was penalized. The only

exceptions to this policy were the first two services where they were permitted to overcollect unpenalized all the way up to half the needed variable costs (total out-of-pocket plus variable support) not otherwise recovered through other services; again the rationale was that the most heavily used services were the simplest, most effective means of subsidization. All these considerations were incorporated mathematically in the selection of the appropriate $B_i$ values.

(viii) The fraction f was selected as the ratio of total out-of-pocket costs for all services over the total budget less the variable support recovered through capitation (i.e., the utilities and maintenance). Thus, the variable support cost fraction is being determined in direct relationship to the total out-of-pocket costs. They both increase or decrease together.

(ix) The weights or penalties were chosen so that:

a) more recent years had greater weight

b) overcollecting the total budget was the most severely penalized

c) overcollecting by services beyond their "free" allowances was equally penalized across all services.

(x) Utilities and maintenance expenses were recovered on the basis of head counts for all institutions; those institutions without in-house library facilities were assessed double those with since they presumably needed these facilities more.

Based on an estimated budget, broken down by line item expenditures, the model was run. Overall usage data by institution is shown in Table II-4.* The unit charges output are listed in Table II-5. The consequent usage based assessments to each institution by service is given in Table II-6, and the total assessments are given in Table II-7. The base fee component shown in Table II-7 is discussed in the next part of this report.

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*The abbreviations for the institutions are: Baylor Medical School (BAYLOR); Houston Academy of Medicine (HAM); Texas Women's University (TWU); University of Texas Health Science Center (UTHSC) consisting of the Medical School (MS), Graduate School of Biomedical Sciences (GSBS), School of Allied Health (SAH), Speech and Hearing Institute (SHI), School of Nursing (UTSSN), Dental Branch (DB), and School of Public Health (SPH); University of Texas System Cancer Center M. D. Anderson Hospital and Tumor Institute (UTMDA); Prairie View A & M University School of Nursing (PVAMUSN); Texas Institute of Rehabilitation and Research (TIRR); Texas Research Institute of Mental Sciences (TRIMS); Institute of Religion (IRELIGION); Harris County Hospital District (HCHD); Hermann Hospital (HERMANN); Methodist Hospital (METHODIST); St. Luke's Episcopal/Texas Children's Hospital (SL/TCH); Memorial Hospital (MEMORIAL); St. Joseph Hospital (ST.JOSEPH); Veterans Administration Hospital (VA).

Table II-4: USE OF LIBRARY SERVICES BY INSTITUTIONS (UNITS)

| INSTITUTION | S.S. | CIRC | ILL | REF<10 | REF≥10 | ILB | MAN.BIB | COMP.S |
|---|---|---|---|---|---|---|---|---|
| | SERVICE | | | | | | | |
| BAYLOR | 125318 | 51360 | 0 | 4747 | 170 | 890 | 12 | 1021 |
| HAM | 8296 | 3400 | 0 | 2114 | 94 | 69 | 43 | 426 |
| TWU | 76091 | 31185 | 0 | 3113 | 120 | 83 | 0 | 162 |
| UTHSC | (90947) | (38094) | ( 492) | (3843) | ( 163) | ( 455) | ( 26) | ( 978) |
| MS | 45513 | 17835 | 0 | 1714 | 98 | 193 | 24 | 695 |
| GSBS | 13906 | 5698 | 0 | 214 | 7 | 167 | 0 | 45 |
| SAH | 3379 | 1385 | 0 | 67 | 0 | 0 | 0 | 0 |
| SHI | 2545 | 1043 | 0 | 96 | 5 | 24 | 0 | 7 |
| UTSSN | 16543 | 6780 | 0 | 934 | 41 | 7 | 0 | 14 |
| DR | 5412 | 2218 | 264 | 228 | 0 | 12 | 0 | 29 |
| SPH | 7649 | 3135 | 228 | 590 | 12 | 52 | 2 | 188 |
| UTMDA | 7413 | 3038 | 2052 | 415 | 7 | 0 | 0 | 0 |
| PVAMUSN | 4038 | 1655 | 0 | 120 | 2 | 0 | 0 | 2 |
| TIRR | 1130 | 463 | 2268 | 142 | 2 | 0 | 0 | 57 |
| TRIMS | 1398 | 573 | 1764 | 96 | 10 | 0 | 0 | 64 |
| I RELIGION | 1459 | 598 | 0 | 53 | 0 | 10 | 0 | 19 |
| HCHD | 2843 | 1165 | 0 | 74 | 2 | 0 | 0 | 19 |
| HERMANN | 5453 | 2235 | 108 | 137 | 0 | 7 | 0 | 31 |
| METHODIST | 5546 | 2273 | 0 | 238 | 7 | 7 | 0 | 26 |
| SL/TCH | 4978 | 2040 | 468 | 226 | 19 | 7 | 0 | 60 |
| MEMORIAL | 378 | 155 | 0 | 10 | 0 | 2 | 0 | 0 |
| ST. JOSEPH | 434 | 178 | 0 | 29 | 2 | 0 | 0 | 0 |
| VA | 1501 | 615 | 0 | 106 | 7 | 2 | 0 | 0 |
| TOTAL USAGE | 341223 | 139027 | 7152 | 15463 | 605 | 1532 | 81 | 2865 |

Table II-5: UNIT CHARGES FOR LIBRARY SERVICES

| | SERVICE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | R.S. | CIRC | ILL | REF<1H | REF>1H | ILP | MAN.PIH | COMP.S |
| AVERAGE UNIT CHARGE | .3H | 1.7H | 2.1H | 2.5H | 5.HH | 7.HH | 5H.36 | 12.33 |
| TOTAL COLLECTED | 1H2H21.75 | 236189.25 | 15698.HH | 38657.5H | 262H.83 | 5144.56 | 4HHH.HH | 35323.11 |

Table II-6: ASSESSMENTS TO INSTITUTIONS FOR USE OF LIBRARY SERVICES (DOLLARS)

| INSTITUTION | SERVICE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S.S. | CIRC | ILL | REF<10 | REF≥10 | TLR | MAN.BIB | COMP.S | TOTAL |
| BAYLOR | 3746A,64 | A7254,13 | A,AA | 11867,50 | 736,43 | 298A,6A | 712,3A | 12588,1A | 153615,77 |
| HAM | 2489,A1 | 5776,17 | A,AA | 5285,AA | 4A7,2A | 231,71 | 2552,4A | 5252,23 | 21985,11 |
| TWU | 22759,33 | 52979,36 | A,AA | 7782,5A | 519,83 | 27A,72 | A,AA | 1997,33 | 863AA,AA |
| UTHSC | ( 2838A,A6) | ( 64716,8A) | ( 1079,35) | ( 96A7,5A) | ( 7A6,11) | ( 1527,92) | ( 1543,31) | ( 12A57,94) | (119627,A6) |
| MS | 13647,86 | 30299,4A | A,AA | 4285,AA | 424,53 | 64A,11 | 1424,59 | 8568,7A | 59258,2A |
| GSBS | 4157,73 | 9680,1A | A,AA | 535,AA | 3A,32 | 56A,8A | A,AA | 554,81 | 15518,85 |
| SAH | 1A1A,2A | 2352,94 | A,AA | 167,5A | A,AA | A,AA | A,AA | A,AA | 3534,72 |
| SHI | 76A,93 | 1771,92 | A,AA | 24A,AA | 21,66 | 8A,59 | A,AA | 86,3A | 2961,41 |
| UTSSN | 49AA,17 | 11518,36 | A,AA | 2335,AA | 177,61 | 23,51 | A,AA | 172,61 | 19173,25 |
| DA | 1618,13 | 376A,1A | 579,16 | 57A,AA | A,AA | 4A,3A | A,AA | 357,55 | 6933,23 |
| SPH | 2286,96 | 5325,97 | 5AA,18 | 1475,AA | 51,98 | 174,62 | 118,72 | 2317,89 | 12251,32 |
| UTMDA | 2216,4A | 5161,1A | 4581,66 | 1A37,5A | 3A,32 | A,AA | A,AA | A,AA | 12947,A6 |
| PVAMUSN | 1247,32 | 2A11,64 | A,AA | 3AA,AA | A,66 | A,AA | A,AA | 24,66 | 4352,27 |
| TIPR | 337,A6 | 7A6,58 | 4975,52 | 355,AA | A,66 | A,AA | A,AA | 7A2,76 | 7166,3A |
| TRIMS | 417,99 | 973,45 | 3869,85 | 24A,AA | 43,32 | A,AA | A,AA | 7A9,A7 | 6333,6A |
| T RELIGION | 436,22 | 1A15,93 | A,AA | 132,5A | A,AA | 33,5A | A,AA | 234,25 | 1A52,49 |
| HCHD | A5A,A2 | 1979,19 | A,AA | 185,AA | A,66 | A,AA | A,AA | 234,25 | 3257,13 |
| HERMANN | 1639,3A | 3796,98 | 236,93 | 342,5A | A,AA | 23,51 | A,AA | 3A2,2A | 6412,51 |
| METHODIST | 1658,19 | 3861,54 | A,AA | 595,AA | 3A,32 | 23,51 | A,AA | 32A,56 | 6AA9,12 |
| SLATCH | 14AA,36 | 3465,7A | 1A26,69 | 565,AA | 82,31 | 23,51 | A,AA | 739,75 | 7391,33 |
| MEMORIAL | 113,A2 | 263,33 | A,AA | 25,AA | A,AA | 6,72 | A,AA | A,AA | 4AA,A6 |
| ST. JOSEPH | 129,76 | 3A2,4A | A,AA | 72,5A | A,66 | A,AA | A,AA | A,AA | 513,32 |
| VA | 4AA,78 | 1A44,81 | A,AA | 265,AA | 3A,32 | 6,72 | A,AA | A,AA | 1795,63 |
| TOTALS | 192A21,75 | 236189,25 | 15698,AA | 38657,5A | 2629,83 | 5148,56 | 4AA8,AA | 35323,11 | 44A455,AA |

## Table II-7: ASSESSMENTS TO INSTITUTIONS (DOLLARS)

| INSTITUTION | HEAD COUNT | HEAD COUNT ASSESSMENT ($28.68 PER HEAD)** | USAGE ASSESSMENT | BASE FEE | TOTAL ASSESSMENT |
|---|---|---|---|---|---|
| BAYLOR | 3003 | 86136,02 | 153615,77 | 185626,00 | 425377,79 |
| HAM | 2123 | 60894,69 | 21985,11 | 35391,00 | 118269,81 |
| TWU | 1063 | 30490,37 | 86308,08 | 30468,00 | 147266,45 |
| UTHSC | ( 2422) | ( 53504,79) | (119627,06) | (293173,00) | ( 466304,85) |
| MS | 577 | 16550,28 | 59258,28 | 274676,00 | 350484,56 |
| GSBS | 205 | 5880,08 | 15518,85 | 0,00 | 21398,93 |
| SAH | 81 | 2323,35 | 3530,72 | 0,00 | 5854,07 |
| SHI | 20 | 573,67 | 2961,41 | 0,00 | 3535,07 |
| UTSSN | 432 | 12391,20 | 19173,25 | 0,00 | 31564,45 |
| DR* | 737 | 10569,80 | 6933,23 | 11695,00 | 29198,03 |
| SPH* | 370 | 5306,41 | 12251,32 | 6802,00 | 24359,74 |
| UTMDA * | 527 | 7558,06 | 12947,06 | 15537,00 | 36042,12 |
| PVAMUSN* | 88 | 1262,07 | 4352,27 | 2670,00 | 8284,34 |
| TIRR | 42 | 1204,70 | 7166,38 | 1758,00 | 10129,08 |
| TRIMS* | 44 | 631,03 | 6333,68 | 1295,00 | 8259,71 |
| I RELIGION | 101 | 2897,02 | 1852,49 | 2001,00 | 6750,50 |
| HCHD | 54 | 1548,90 | 3257,13 | 1636,00 | 6442,03 |
| HERMANN | 11 | 315,52 | 6412,51 | 1393,00 | 8121,02 |
| METHODIST | 103 | 2954,38 | 6489,12 | 2243,00 | 11686,50 |
| SL/TCH | 66 | 1893,10 | 7391,33 | 2122,00 | 11406,42 |
| MEMORIAL | 50 | 1434,17 | 408,06 | 1758,00 | 3600,23 |
| ST. JOSEPH | 55 | 1577,58 | 513,32 | 1515,00 | 3605,91 |
| VA* | 36 | 516,30 | 1795,63 | 489,00 | 2800,93 |
| TOTALS | 9788 | 254908,68 | 440455,00 | 579065,00 | 1274428,68 |

*This institution has its own library.
**For institutions with their own library the assessment is $14.34 per head.